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(54) **An optical interference, electroluminescent device having low reflectance**

Optische elektrolumineszente Interferenz-Vorrichtung mit niedriger Reflexion

Dispositif optique d'interférence électroluminescent à faible réflectivité

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## Description

This invention relates to an optical interference electroluminescent device having a low reflectance.

Electroluminescent devices typically consist of an electroluminescent layer, sometimes sandwiched between dielectrics, with electrodes attached to both sides. With the application of a voltage on the electrodes, light is emitted from the electroluminescent layer and through the electrodes, if they are transparent. When viewed under high ambient light illumination, the light that reaches the observer is composed of the emitted light and the ambient light reflected by the device. If  $L_{on}$  is the emitted luminance,  $R$  is the reflectance of the device and  $I_{amb}$  is the ambient illuminance, then the signal-to-reflected ambient light ratio (SRA) can be written as

$$SRA = L_{on} / (R \cdot I_{amb}) \quad (1)$$

Clearly, a high SRA is desirable and under a given ambient light illumination, this can be achieved by either increasing the brightness or decreasing the reflectance of the device.

Of particular interest are the devices capable of displaying images. Electronic displays, particularly light emitting displays, are frequently limited in applications involving high ambient light levels, e.g. direct sunlight, because of their high reflectance of ambient light and, hence, the tendency of the displayed imagery to "wash-out".

An image on a display is formed using activated picture elements (ON pixels with a luminance  $L_{on}$ ) of the display screen which have a higher luminance relative to the screen background. The screen background for a particular image is comprised of inactive pixels (OFF pixels with a luminance  $L_{off}$ ) along with the passive elements of the display, i.e. the area between the pixels.

The legibility of a displayed image can be quantitatively defined in terms of a contrast ratio. If the reflectance of the pixels is  $R$  and the ambient illuminance is  $I_{amb}$  then, if the passive elements of the display are ignored for simplicity, the contrast ratio (CR) can be written as,

$$CR = (L_{on} + R \cdot I_{amb}) / (L_{off} + R \cdot I_{amb}). \quad (2)$$

If the contrast ratio is less than a certain value, degraded legibility results and the display may be judged inadequate. For high ambient illumination, the contrast ratio deteriorates and CR tends to unity unless either  $L_{on}$  is increased or else the reflectance of the ambient light by the pixels can be minimized.

Previous attempts to improve the contrast ratio, and hence the legibility of electronic displays, have included the use of anti-reflecting coatings on the outside of displays and auxiliary filter elements such as polarizers, band-pass filters, neutral density filters, louvred screens, plastic meshes, etc. With some of these methods, the brightness of the display has been compromised, sometimes to an unacceptable degree. Increasing the luminance of the pixels to compensate for this effect can lead to a shorter life and reliability problems.

One important electro-optical device is the electroluminescent device which has several distinguishing attributes: low power, potentially high contrast, light weight, wide viewing angle, nonlinear luminescence versus voltage characteristics important for matrix addressing, and a multi-colour capability. A typical ac electroluminescent device is composed of the electro-optical members functioning as,

- a) a front transparent electrode,
- b) a first transparent dielectric,
- c) an electroluminescent member,
- d) a second dielectric and,
- e) a rear or counter electrode.

In some cases, the dielectrics (b) and (d) are omitted allowing dc operation of the device. With the application of a voltage across the electrodes, a high electric field can be generated across the electroluminescent member which results in electroluminescence. The dielectric layers are used to limit the current in the device and prevent a catastrophic breakdown of the electroluminescent member, however, the device is then electrically a capacitor, hence, requiring an ac voltage to be applied across the electrodes. For large area displays, the counter electrode must have a low electrical resistivity, and hence, this usually requires it be made out of a metal such as aluminum. Unfortunately, this results in a device having a large reflectance in the visible portion of the optical spectrum.

One particular application of the electroluminescent device is a display in which pixels or, more generally patterns, are formed when areas of the front (a) and rear (e) electrodes partially overlie one another in the viewing direction. The metal counter electrode reflects the ambient light strongly, and hence, under high ambient light illumination, results in a low contrast ratio for the display.

DE-A-3 231 727 discloses an electroluminescent display device of this type. To improve the contrast ratio, the device is provided with a black layer which is semi-conducting and highly dispersive. This layer has sufficient optical

dispersion in the visible spectrum to induce absorption between the second dielectric layer and the counter electrode.

There remains a need for an electroluminescent device wherein the contrast ratio of the device is significantly improved by the device having a low overall reflectance of the ambient light. The applicants have found that this can be accomplished according to the present invention, using the thin film phenomenon known in the art as optical interference.

Optical interference is defined as the variation of electromagnetic wave amplitude with distance or time, caused by the superposition of two or more waves of electromagnetic radiation (light). These two or more waves can be the result of reflection or transmission at the interfaces of thin film multilayer structures, used in the present invention, provided that the thickness of the individual films and layers are sufficient to support optical interference at the wavelengths of interest.

It has been proposed in United States Patent No. 4,287,449, dated September 1, 1981, "Light-Absorption Film for Rear Electrodes of Electroluminescent Display Panel", M. Takeda et al, to provide a display panel having at least one light absorbing layer placed between a rear dielectric layer and a counter electrode for absorbing ambient light transmitted through a transparent electrode. A plurality of light absorbing layers may be formed in the same arrangement. Materials useful for the light absorbing layers are  $Al_2O_3$ ,  $Al_2O_{3-x}$ , Mo, Zr, Ti, Y, Ta, Ni, Al or the like with a thickness of about 10-300 Å.

Intrinsic absorption of light is defined as the process whereby some of the energy of electromagnetic radiation (light) is transferred to a substance on which it is incident or which it traverses. It is possible to significantly enhance the amount of absorption of light in a thin film multilayer structure, through the phenomenon of optical interference, over that of intrinsic absorption alone provided, that as stated above, the thicknesses of the individual films and layers are sufficient to support optical interference at the wavelengths of interest. This phenomenon is hereinafter referred to as optical interference enhanced absorption.

The Takeda et al devices, while useful, are primarily concerned with intrinsic absorption alone of the ambient light because the layers are of thicknesses which are not capable of minimizing reflectance of light by optical interference enhanced absorption.

According to the present invention there is provided an optical interference, electroluminescent device having low reflectance, comprising:

- (a) an electroluminescence transmitting, electro-optical, front electrode comprising at least one layer,
- (b) an electro-optical counter electrode, disposed to the rear of the front electrode and comprising at least one layer,
- (c) an electro-optical electroluminescent member, comprising at least one layer, and disposed between the front electrode and the counter electrode, and characterised by
- (d) for at least one of the electro-optical members, an optical member in interfacial contact therewith such that at least an optical member is in interfacial contact with said counter electrode, the optical member comprising at least one optical interference film which is substantially transparent to ambient light in that said at least one optical interference film has an extinction coefficient such that at least about 90% of the incident light is transmitted per se at a predetermined wavelength and is of a thickness and material such that the spectral reflectance of said electroluminescent device is so modified that the reflectance at ambient light by the electroluminescent device towards a viewer is reduced by optical interference of light partially reflected at the interfaces of said at least one film in combination with that of light partially reflected at the layers of said electro-optical members.

The said at least one optical member may comprise at least one further film which is partially absorbing with respect to visible light, so that the spectral reflectance and absorptance of the device are modified by the thicknesses and materials of the substantially transparent and partially absorbing films of that optical member in combination with the thicknesses and materials of the electro-optical members, so that the reflectance of ambient light by the device towards the viewer is further reduced by optical interference enhanced absorption of light caused by the said at least one further film.

Thus, in contrast to Takeda et al, the applicants' invention uses optical interference, and if desired, optical interference enhanced absorption to achieve low reflectance.

The device may further comprise:

- a) a first dielectric, electroluminescence transmitting, electro-optical member, comprising at least one layer, between the front electrode electro-optical member and the electroluminescent electro-optical member, and
- b) a second dielectric, electroluminescence transmitting, electro-optical member, comprising at least one layer, between the counter electrode electro-optical member and the electroluminescent electro-optical member, and in

these embodiments,

c) the said at least one of the electro-optical members includes the first and second dielectric electro-optical members.

5 The thicknesses and materials of the layers of the electro-optical members in the device may be chosen to further reduce the reflectance of the device by optical interference.

When the said at least one optical member includes a partially absorbing film,

a) the counter electrode electro-optical member may have high reflectance, and

10 b) the said at least one of the optical members may be in interfacial contact with the front face of the counter electrode electro-optical member, so that the reflectance of light from the counter-electrode electro-optical member is reduced throughout the visible spectrum, including the wavelengths at which the electroluminescence is emitted, by the process of optical interference enhanced absorption.

15 In other embodiments where the said at least one optical member includes a partially absorbing film,

a) the counter electrode electro-optical member has low reflectance and high transmittance at the wavelengths in which the electroluminescence is emitted, and

20 b) the said at least one of the optical members is the interfacial contact with the rear face of the counter electrode electro-optical member, and,

c) the substantially transparent and partially absorbing films of the optical members are of such thicknesses, and materials that, at the wavelengths at which the electroluminescence is emitted, the reflectance is high to increase the brightness of the device, while at other wavelengths the absorptance of light is high to reduce the reflectance of ambient light of the device towards the viewer at these other wavelengths.

25 In yet other embodiments where the said at least one optical member includes a partially absorbing film,

a) the counter electrode electro-optical member has high reflectance, and

b) the said an optical member is in interfacial contact with the front face of said counter electrode, and

30 c) the substantially transparent and partially absorbing films of that optical member are of such thicknesses and materials that, at the wavelengths at which the electroluminescence is emitted, the transmittance through that optical member is high, while at other wavelengths the absorptance of light is high to reduce the reflectance of ambient light of the device towards the viewer at these other wavelengths.

35 In yet other embodiments of the present invention, the front and counter electrode electro-optical members each comprise one of a plurality of electrode electro-optical members, with the front electrode electro-optical members partially overlying areas of the counter electrode electro-optical members to form a display depicting device.

When composed of a plurality of electrode electro-optical members, the front and counter electrode electro-optical members may form the grid system of a pixel display depicting device.

40 Further, when a plurality of the electrode electro-optical members are present, the thicknesses and materials of the films and layers at areas of different overlays may be such that, by the process of optical interference, different overlay areas of the device have substantially the same reflectance and transmittance so that a substantially uniform appearance of the display is viewed when no electroluminescence is being emitted.

45 The said at least one optical film which is substantially transparent may have an optical thickness, defined to be the product of refractive index and metric thickness, of at least about  $0.035 \mu\text{m}$  with an extinction coefficient such that at least about 90% of the incident light is transmitted per se at a predetermined wavelength.

The said at least one further optical film which is partially absorbing may have a transmittance per se of at least about 35% at a predetermined wavelength.

50 Thus the present invention provides an optical interference, electroluminescent device having low reflectance, which contains at least one optical member comprising at least one film whose material and thickness are compatible with the proper electro-optical operation of the device and are such as to support the known process of thin film optical interference phenomena. There may be additional films in the optical member that are not required for optical interference but which enhance the compatibility of the optical member with the electro-optical member in interfacial contact therewith. The materials and thicknesses of the layers of the electro-optical members may be selected to yield low reflectance of the ambient light from the complete device. Furthermore, the materials and thicknesses of each film in an optical member may be such that the optical member can either minimize the reflection of ambient light at the front interface of the electro-optical component interfacing therewith or minimize the total reflection of ambient light from the complete device. By using the optical members in interfacial contact with the electro-optical members a better per-

formance, i.e. lower reflectance, can be achieved and more relaxed requirements on the layers of the electro-optical members can be obtained.

Tests to verify the present invention have shown that the incorporation of optical members in the design of electroluminescent display devices can significantly improve the contrast ratio (CR) and legibility characteristics of the display in the presence of sunlight. Tests to verify the present invention have also shown that optical members for use in electroluminescent devices can be readily designed and fabricated for ambient light absorption, transmission or reflection over a wide range of spectral bandwidths and angles of incidence, depending on the needs of the particular device.

In the accompanying drawings which illustrate, by way of example, embodiments of the present invention;

Figure 1 is an enlarged, diagrammatic end view of an optical interference, electroluminescent device having low reflectance,

Figure 2 is a graph in which the spectral reflectance of a known device is compared with the spectral reflectance of two embodiments of the device shown in Figure 1,

Figure 3 is a graph of the spectral reflectance and absorptance of an optical interference electroluminescent device which behaves as a wideband absorber with narrowband reflection at the electroluminescent wavelengths,

Figure 4 is a graph of the spectral transmittance and absorptance of an optical interference electroluminescent device which behaves as a wideband absorber with narrowband transmission at the electroluminescence wavelengths,

Figure 5 is an enlarged, diagrammatic front view of a portion of an optical interference, electroluminescent display device having low reflectance, and

Figure 6 is an side view along I-V, Figure 5.

Referring to Figure 1, there is shown an optical interference, electroluminescent device, generally designated 1, having low reflectance, comprising:

a) an electroluminescence transmitting front electrode, electro-optical member 2, comprising in this embodiment two layers 4 and 6,

b) a counter electrode, electro-optical member 8, comprising one layer, to the rear side of the front electrode electro-optical member 2,

c) an electroluminescent, electro-optical member 10, comprising one layer, between the front electrode electro-optical member 2 and the counter electrode electro-optical member 8, and

d) for at least one of the electro-optical members 2, 8 and 10, an optical member, in this embodiment optical members 12, 14, 16 and 18, in interfacial contact therewith, the optical members 12, 14, 16 and 18 each comprising at least one optical interference film 20, 22, 24 and 26 respectively, which is substantially transparent to ambient light, whereby the spectral reflectance of the device is modified by the thicknesses and materials of the films 20, 22, 24 and 26 being chosen for the thicknesses and materials of the electro-optical members 2, 8 and 10, such that the reflectance of ambient light X by the device 1 towards the viewer in for example directions Y and Z, is reduced by optical interference of light partially reflected at the interfaces of each of the films 20, 22, 24 and 26 in combination with that of light partially reflected at interfaces of the layers of the electro-optical members 2, 8 and 10.

In this embodiment the electro-optical members 2, 8 and 10 and the optical members 12, 14, 16 and 18 are coatings on a glass substrate 28.

The layers 4 and 6 of the front electrode electro-optical member 2 may be a transparent layer of indium tin oxide (ITO) and gold.

The counter electrode electro-optical member 8 may be of aluminum.

The electroluminescent electro-optical member 10 may be of ZnS:Mn.

The substantially transparent optical interference films 20, 22, 24 and 26 of the optical members 12, 14, 16 and 18 may be substantially transparent films of  $\text{Al}_2\text{O}_3$ ,  $\text{SiO}_2$ ,  $\text{ZrO}_2$ ,  $\text{HfO}_2$ ,  $\text{Sc}_2\text{O}_3$ ,  $\text{TiO}_2$ , ITO,  $\text{La}_2\text{O}_3$ ,  $\text{MgO}$ ,  $\text{Ta}_2\text{O}_5$ ,  $\text{ThO}_2$ ,  $\text{Y}_2\text{O}_3$ ,  $\text{CeO}_2$ ,  $\text{AlF}_3$ ,  $\text{CeF}_3$ ,  $\text{Na}_3\text{AlF}_6$ ,  $\text{LaF}_3$ ,  $\text{MgF}_2$ ,  $\text{ThF}_4$ ,  $\text{ZnS}$ ,  $\text{Sb}_2\text{O}_3$ ,  $\text{Bi}_2\text{O}_3$ ,  $\text{PbF}_2$ ,  $\text{NdF}_3$ ,  $\text{Nd}_2\text{O}_3$ ,  $\text{Pr}_6\text{O}_{11}$ ,  $\text{SiO}$ ,  $\text{NaF}$ ,  $\text{ZnO}$ ,  $\text{LiF}$ ,  $\text{GdO}_3$  or of other suitable thin film materials known to those skilled in the art. The optical thickness of the substantially transparent films, defined to be the product of refractive index and metric thickness, should preferably be at least about  $0.035 \mu\text{m}$  with an extinction coefficient such that preferably at least about 90% of the incident light is transmitted per se at a predetermined wavelength.

In some embodiments of the present invention at least one of the optical members 12, 14, 16 and 18 comprise at least one further film 30, 32, 34 and 36 respectively, which is partially absorbing with respect to visible light, whereby the spectral reflectance and absorptance of the device 1 are modified by the thicknesses and materials of the substantially transparent and partially absorbing films, 20, 22, 24, 26 and 30, 32, 34, 36 respectively, of the optical members

12, 14, 16 and 18 respectively, in combination with the thicknesses and materials of the layers of the electro-optical members 2, 8 and 10, such that the reflectance of ambient light X by the device towards the viewer in, for example, directions Y and Z, is further reduced by optical interference absorption of light caused by the further partially absorbing films 30, 32, 34 and 36.

The partially light absorbing films 30, 32, 34 and 36 may, for example, be of Al, Cu, Au, Mo, Ni, Pt, Rh, Ag, W, Cr, Co, Fe, Ge, Hf, Nb, Pd, Re, V, Si, Se, Ta, Y, Zr, as well as alloys of these metals such as Inconel, Nichrome and the like, or any absorbing oxides of these metals or their alloys thereof. For partially absorbing films, the extinction coefficient and thickness of the film should be such that the transmission through the film at the predetermined wavelength, neglecting optical interference, should preferably be at least about 35%.

The device 1 described so far is particularly suitable with a dc voltage applied between the electrode electro-optical members 2 and 8.

To stabilize the electroluminescent electro-optical member 10 against electrical breakdown, the device 1 may further comprise;

a) a first dielectric electro-optical member 38, comprising at least one layer, in the embodiment two layers 40 and 42, between the front electrode electro-optical member 2 and the electroluminescent electro-optical member 10, and

b) a second dielectric electro-optical member 44, comprising at least one layer, in this embodiment two layers 46 and 48, between the counter electrode electro-optical member 8 and the electroluminescent electro-optical member 10, and

c) for at least one of the electro-optical members 2, 8, 10, 38 and 44 one of the optical members 12, 14, 16, 18, 50 and 52 may be provided. That is, the first and second dielectric electro-optical members 38 and 44, when included, may be provided with at least one of the optical members 50 and 52, comprising films 54 and 56 which are substantially transparent and, if desired, films 58 and 60 which are partially absorbing with respect to visible light. The optical members 50 and 52 are in interfacial contact with the first and second dielectric electro-optical members 38 and 44, respectively. The spectral reflectance of the device is modified by the thicknesses and materials of each of the films 20, 22, 24, 26, 30, 32, 34, 36, 54, 56, 58 and 60, being chosen for the thicknesses and materials of the electro-optical members 2, 8, 10, 38 and 44 such that the reflectance of ambient light X by the device 1 towards the viewer in, for example, directions Y and Z, is reduced by optical interference of light partially reflected at the interfaces of any of the films 20, 22, 24, 26, 30, 32, 34, 36, 54, 56, 58 and 60 present, in combination with that of light partially reflected at interfaces of the layers of the electro-optical members 2, 8, 10, 38 and 44. To operate the device with the dielectric electro-optical members 38 and 44 present, an ac voltage is applied across the electrode electro-optical members 2 and 8.

In some embodiments of the present invention, the thicknesses and materials of the layers of the electro-optical members 2, 8, 10 and, if present, 38 and 44, are chosen to further reduce the reflectance of the device 1 by optical interference.

In other embodiments of the present invention, when the optical member 14 includes a partially absorbing film 32,

a) the counter electrode electro-optical member 8 may have high reflectance, and

b) at least the optical member 14 is present, which is in interfacial contact with the front face of the counter electrode electro-optical member 8, the optical member 14 being such that the reflectance of light from the counter electrode electro-optical member 8 is reduced throughout the visible spectrum, including the wavelengths at which the electroluminescence is emitted, by the process of optical interference enhanced absorption.

In the following Table I, details of specific examples of devices according to the present invention are given together with those of a comparable, known device.

In Table I, three devices are shown as Systems a, b and c. System a corresponds to the prior art, a known device comprised of five electro-optical members 2, 8, 10, 38, and 44 deposited on a glass substrate 28 in the sequential order shown in Table I. The materials and metric thicknesses of the electro-optical members 2, 8, 10, 38, and 44 are also shown in Table I, and are typically those used in the prior art. System b is a specific example of the embodiment of the present invention wherein the optical member 14 is comprised of substantially transparent films, 22, of  $ZrO_2$  and partially absorbing films, 32, of Inconel, and the optical member 14 is in interfacial contact with the front face of the counter electrode electro-optical member 8 which is aluminum and has a high reflectance. The materials and thicknesses of the films in the optical member 14, shown in Table I for System b, have been chosen such that the reflectance of light from the counter electrode electro-optical member 8 is reduced throughout the visible spectrum, including the wavelengths at which the electroluminescence is emitted. System c is a specific example of the embodiment of the present invention wherein the thicknesses and materials of the layers of the electro-optical members 2, 8, 10, 38, and

44, shown in Table I, were chosen along with the films of the optical member 14, to further reduce the reflectance of device 1 by optical interference.

Table I

| Member<br>(Fig. 1)      | Deposition<br>Sequence | Material               | Film and Layer Thickness ( $\mu\text{m}$ ) |          |          |
|-------------------------|------------------------|------------------------|--------------------------------------------|----------|----------|
|                         |                        |                        | System a                                   | System b | System c |
| 28                      | Substrate              | Glass                  | 2mm                                        | 2mm      | 2mm      |
| 2                       | 1                      | ITO                    | 0.2000                                     | 0.2000   | 0.1163   |
| 38                      | 2                      | $\text{Y}_2\text{O}_3$ | 0.3000                                     | 0.3000   | 0.2567   |
| 10                      | 3                      | $\text{ZnS:Mn}$        | 0.6000                                     | 0.6000   | 0.4690   |
| 44                      | 4                      | $\text{Y}_2\text{O}_3$ | 0.3000                                     | 0.3000   | 0.1690   |
| 14                      | 5                      | Inconel                | —                                          | 0.0013   | 0.0013   |
|                         | 6                      | $\text{ZrO}_2$         | —                                          | 0.0510   | 0.0338   |
|                         | 7                      | Inconel                | —                                          | 0.0119   | 0.0098   |
|                         | 8                      | $\text{ZrO}_2$         | —                                          | 0.0521   | 0.0519   |
| 8                       | 9                      | Al                     | opaque                                     | opaque   | opaque   |
| Luminous<br>Reflectance |                        |                        | 83.6%                                      | 3.1%     | 1.8%     |

The spectral reflectances (R) of the devices given in Table I are shown in Figure 2, together with  $V(\lambda)$ , the standard photopic observer curve. In Figure 2, (—) designated System a, (— - —) designates System b, and (— · — · —) designates System c.

The luminous reflectance shown in Table I for each of the three systems is defined as the integrated produce of  $V(\lambda)$  with the reflectance  $R(\lambda)$  of a system divided by the integral of  $V(\lambda)$ . As seen in Table I, the luminous reflectance decreases from 83.6% for System a to 3.1% for System b. Choosing the thicknesses of the layers of the electro-optical members 2, 8, 10, 38, and 44 and the films of the optical member 14, System c, further reduces the luminous reflectance to 1.8%. Thus there is a substantial reduction in the reflectance of the devices in the present invention compared to the prior art.

The optical member 14 in System b allows the reflectance of light from the counter electrode electro-optical member 8 to be reduced by the previously defined process of optical interference enhanced absorption. Light incident upon the partially absorbing Inconel films 32 is partially reflected, absorbed or transmitted. The light that is transmitted through the Inconel films 32 is primarily reflected back towards the viewer by the counter electrode electro-optical member 8. As well, this light is also partially reflected back again to the aluminum layer 8 by the Inconel films 32. By choosing the thicknesses of the films 22 and 32 in the optical member 14 properly, the light reflected towards the viewer from the counter electrode member 8 is then out of phase with the light partially reflected back towards the viewer from the Inconel layers 32, and hence the light reflected towards the viewer from both the Inconel films 32 and the aluminum layer 8 destructively interfere and cancel out. The overall effect is that a substantial amount of the light incident upon the device 1 is trapped between the Inconel films 32 and the aluminum layer 8, and is reflected back and forth between these films 32 and aluminum layer 8 until the trapped light has been completely absorbed in the partially absorbing films 32 and the counter electrode electro-optical member 8.

Numerical calculations were performed to determine the difference between intrinsic absorption and optical interference enhanced absorption in the partially absorbing films 32. For System b, if the substantially transparent films 22 were not present, the total absorption of light by the partially absorbing films 32 would be 65% at the wavelength of 0.550  $\mu\text{m}$ . With the substantially transparent films 22 present, as in System b, optical interference enhances the absorption so that the total absorption of light by the partially absorbing films 32 is 95% at a wavelength of 550 nm, with 4% of the incident light being absorbed by the aluminum layer 8 and less than 1% being reflected from the device 1 back to the viewer.

In yet another embodiment of the present invention where the optical member 16 includes a partially absorbing film 34,

a) the counter electrode electro-optical member 8 has low reflectance and high transmittance at the wavelengths in which the electroluminescence is emitted, and

b) at least the optical member 16 is present which is in interfacial contact with the rear face of the counter electrode electro-optical member 8, and  
 c) the substantially transparent and partially absorbing films 24 and 34, respectively, of the optical member 16 are of such thicknesses and materials that, at the wavelengths at which the electroluminescence is emitted, the reflectance is high to increase the brightness of the device, while at other wavelengths the absorptance of light is high to reduce the reflectance of ambient light of the device 1 towards the viewer at these other wavelengths.

The theoretical reflectance and absorptance of this embodiment according to the present invention is shown in Figure 3, where the device behaves as a wideband absorber with narrowband reflection at an electroluminescence wavelength  $\lambda_{EL}$ . In Figure 3, (—) designates the absorptance (A) of the device while (-----) designates the reflectance (R) of the device.

In one specific example of this embodiment the optical member 16 is a quarter-wave stack  $(HL)^N HS$ , where H is a substantially transparent film 24 with a quarter wave optical thickness at  $\lambda_{EL}$  and with a high refractive index  $n_H$ . L is a substantially transparent film 24 with a quarter wave optical thickness at  $\lambda_{EL}$  and with a low refractive index  $n_L$ , and S represents a stack of substantially transparent and partially absorbing films 24 and 34, respectively, with a wideband absorptance across the visible light spectrum. The half-width of the reflectance peak at  $\lambda_{EL}$  is determined by the ratio  $r=(n_H/n_L)$ , where as  $r$  approaches 1, the half-width decreases. The maximum reflectance at  $\lambda_{EL}$  is determined by the number of periods in the quarter-wave stack, N, and this maximum reflectance increases as N increases. The half-width and maximum reflectance of the peak at  $\lambda_{EL}$  can be determined by formulas given by, for example, J. A. Dobrowolski in the Handbook of Optics, edited by Walter G. Driscoll, McGraw-Hill Book Co., New York, 1978.

In some embodiments of the present invention,

a) the counter electrode electro-optical member 8 has high reflectance, and  
 b) the said at least one of the optical members is in interfacial contact with the front face of one of the electro-optical members 2, 8, 10, 38 and 44, and  
 c) the substantially transparent (20, 22, 26, 54, and 56) and partially absorbing (30, 32, 36, 58, and 60) films of any of the optical members 12, 14, 18, 50 and 52 present, are of such thicknesses and materials that, at the wavelengths at which the electroluminescence is emitted, the transmittance through that optical member is high, while at other wavelengths the absorptance of light is high to reduce the reflectance of ambient light of the device towards the viewer at these other wavelengths.

The theoretical transmittance and absorptance of this embodiment according to the present invention is shown in Figure 4, where the device behaves as a wideband absorber with narrowband transmission at an electroluminescent wavelength  $\lambda_{EL}$ . In Figure 4, (—) designates the absorptance (A) of the device while (----) designates the transmittance (T) through the electro-optical members 2, 10, 38, and 44 and the said at least one of the optical members 12, 14, 18, 50 and 52 that are in front of the counter electrode electro-optical member 8.

In one specific example of this embodiment the optical member 12 comprises the following stack of nine films:  $Y_2O_3$  (0.0973), Ag (0.0173),  $Y_2O_3$  (0.2493), Ag (0.0095),  $ZrO_2$  (0.0401), Inconel (0.0036),  $ZrO_2$  (0.1448), Inconel (0.0025) and  $ZrO_2$  (0.0705), the numbers within the brackets representing the thicknesses of the layers in  $\mu m$ , and  $Y_2O_3$  and  $ZrO_2$  are each a substantially transparent film 20, and Ag and Inconel are each a partially absorbing film 30 in the stack. The optical member 12 has an induced transmittance of 63% at  $\lambda_{EL}=0.580 \mu m$ , and a reduced luminous reflectance, when viewed by the observer, of 13%. It will be obvious to those practiced in the art that other, higher performance, optical members can be designed.

In Figures 5 and 6, similar parts to those shown in Figure 1 are designated by the same reference numerals and the previous description is relied upon to describe them.

In Figures 5 and 6 the front electrode electro-optical member 2 comprises one of a plurality of front electrode electro-optical members, three of which are shown and designated 2, 62 and 64, and the counter electrode electro-optical member 8 comprises one of a plurality of counter electrode electro-optical members, four of which are shown and designated 8, 66, 68 and 70. The front electrode electro-optical members, such as 2, 62 and 64, overlie areas of the counter electrode electro-optical members, such as 8, 66, 68 and 70, to form a display depicting device 1.

It will be seen that in this embodiment of overlying electrodes, the front and counter electrode optical members, such as 2, 62 and 64, and 8, 66, 68 and 70, form the grid system of a pixel display device 1, with pixels such as pixel 72.

It should be noted that the films 20 and 30 of the optical member 12, if present, are first coated on the glass substrate, by, for example, vacuum deposition through a mask (not shown). The front electrode electro-optical members, such as 2, 62, and 64, are then simultaneously coated as layers 4 and 6 by, for example, vacuum deposition through a mask.

The optical members 14, 18, 50 and 52, and the electro-optical members 10, 38 and 44 are each of then coated, sequentially in their correct order, over the front electrode electro-optical members, such as members 2, 62 and 64 by,



for example, vacuum deposition through masks.

The counter electrode electro-optical members, such as 8, 66, 68 and 70, are then coated simultaneously through a mask by, for example, vacuum deposition on to the optical member 14, and then the optical member 16 is coated through a mask over the counter electrode electro-optical member such as 8, 66, 68 and 70 by, for example, vacuum deposition. Sequentially coating the electro-optical members and the optical members in this manner will cause the members to coat the rear face of the electrode member on which they are deposited and the surfaces between them, such as the spaces 82, 84 and 86 (Figure 6).

From this it will be apparent that there are four areas where different types of overlays are present in the device 1, and these are where,

- i) both of the electrode electro-optical members 2 and 8 are present, and these are pixels, such as pixel 72,
- ii) only the front electrode electro-optical member 2 is present, such as area 90,
- iii) only the counter electrode electro-optical member 8 is present, such as area 92, and
- iv) neither of the electrode electro-optical members 2 and 8 are present, such as area 94.

In some embodiments of the present invention, the thicknesses and materials of the films and layers at the four different types of areas, such as areas 72, 90, 92 and 94, are such that by the process of optical interference, different overlay areas of the device 1 have substantially the same reflectance and transmittance so that a substantially uniform appearance of the display is viewed when no electroluminescence is being emitted. The spectral reflectance of the pixels, such as area 72, can, for example, be reduced as previously described with reference to Table I, System c. It will be self-evident to persons skilled in the art that the reflectance of areas 90, 92, and 94 can be reduced in a similar manner to that described with reference to area 72.

## Claims

1. An optical interference, electroluminescent device having low reflectance, comprising:

(a) an electroluminescence transmitting, electro-optical, front electrode member (2), comprising at least one layer,

(b) an electro-optical counter electrode member (8), disposed to the rear of the front electrode member and comprising at least one layer,

(c) an electro-optical electroluminescent member (10), comprising at least one layer, and disposed between the front electrode member (2) and the counter electrode member (8), and characterised by

(d) for at least one of the electro-optical members (2, 8, 10), an optical member (12, 14, 16, 18) in interfacial contact therewith such that at least an optical member (14, 16) is in interfacial contact with said counter electrode member (8), the optical member (12, 14, 16, 18) comprising at least one optical interference film (20, 22, 24, 26) which is substantially transparent to ambient light in that said at least one optical interference film has an extinction coefficient such that at least about 90% of the incident light is transmitted per se at a predetermined wavelength and is of a thickness and material such that the spectral reflectance of said electroluminescent device is so modified that the reflectance of ambient light by the electroluminescent device towards a viewer is reduced by optical interference of light partially reflected at the interfaces of said at least one film (20, 22, 24, 26) in combination with that of light partially reflected at the layers of said electro-optical members (2, 8, 10).

2. A device according to claim 1, wherein said optical member comprises at least one further film (30, 32, 34, 36) which is partially absorbing with respect to visible light such that the reflectance of ambient light by the electroluminescent device towards the viewer is further reduced by optical interference enhanced absorption.

3. A device according to claim 2, further comprising,

(a) a first dielectric, electroluminescence transmitting, electro-optical member (38), comprising at least one layer, between the front electrode electro-optical member (2) and the electroluminescent electro-optical member (10), and

(b) a second dielectric, electroluminescence transmitting, electro-optical member (44), comprising at least one layer, between the counter electro-optical member (8) and the electroluminescent electro-optical member (10), and wherein,

(c) the said at least one of the electro-optical members (2, 8, 10) of (d), claim 1, includes the first and second dielectric electro-optical members (38, 44).

4. A device according to claims 2 or 3, wherein the thicknesses and materials of the layers of the electro-optical members (2, 8, 10) in the device are chosen to further reduce the reflectance of the device by optical interference.

5. A device according to claims 2, 3 or 4, wherein,

(a) the counter electrode electro-optical member (8) has high reflectance, and

(b) said optical member (14) in interfacial contact with said counter electrode member (8) is in interfacial contact with the front face of the counter electrode member (8), so that the reflectance of light from the counter-electrode member (8) is reduced throughout the visible spectrum, including the wavelengths at which the electroluminescence is emitted, by the process of optical interference enhanced absorption.

6. A device according to claims 2, 3 or 4, wherein,

(a) the counter electrode electro-optical member (8) has low reflectance and high transmittance at the wavelengths in which the electroluminescence is emitted, and

(b) the said at least one of the optical members (16) is in interfacial contact with the rear face of the counter electrode electro-optical member (8), and

(c) the substantially transparent and partially absorbing films (24, 34) of the optical member are of such thicknesses and materials that, at the wavelengths at which the electroluminescence is emitted, the reflectance is high to increase the brightness of the device, while at other wavelengths the absorptance of light is high to reduce the reflectance of ambient light of the device towards the viewer at these other wavelengths.

7. A device according to claims 2, 3 or 4, wherein,

(a) the counter electrode electro-optical member (8) has high reflectance, and

(b) said optical member (14) in interfacial contact with said counter electrode member (8) is in interfacial contact with the front face of said counter electrode member (8), and

(c) the substantially transparent and partially absorbing films (22, 32) of the optical member (14) are of such thicknesses and materials that, at the wavelengths at which the electroluminescence is emitted, the transmittance through that optical member (14) is high, while at other wavelengths the absorptance of light is high to reduce the reflectance of ambient light of the device towards the viewer at these other wavelengths.

8. A device according to claims 1, 2 or 3, wherein the front and counter electrode electro-optical members (2, 8) each comprise one of a plurality of electrode electro-optical members (2, 62, 64; 8, 66, 68, 70), with the front electrode electro-optical members (2, 62, 64) partially overlying areas of the counter electrode electro-optical members (8, 66, 68, 70) to form a display depicting device.

9. A device according to claim 8, wherein the front and counter electrode electro-optical members (2, 62, 64; 8, 66, 68, 70) form the grid system of a pixel (72) display depicting device.

10. A device according to claims 8 or 9, wherein the thicknesses and materials of the films and layers of different overlays are such that for each overlay, by the process of optical interference, different overlay areas of the device have the same reflectance and transmittance so that a substantially uniform appearance of the display is viewed when no electroluminescence is being emitted.

11. A device according to claim 1, wherein the said at least one optical film (20, 22, 24, 26) which is substantially

transparent has an optical thickness of at least about 0.035  $\mu\text{m}$ .

12. A device according to claim 2, wherein the said at least one further optical film (30, 32, 34, 36) which is partially absorbing has a transmittance per se of at least about 35% at a predetermined wavelength.

13. A device according to claim 11 wherein said at least one optical film (20, 22, 24, 26) which is substantially transparent is selected from the group comprising:  $\text{Al}_2\text{O}_3$ ,  $\text{SiO}_2$ ,  $\text{ZrO}_2$ ,  $\text{HfO}_2$ ,  $\text{Sc}_2\text{O}_3$ ,  $\text{TiO}_2$ , ITO,  $\text{La}_2\text{O}_3$ ,  $\text{MgO}$ ,  $\text{Ta}_2\text{O}_5$ ,  $\text{ThO}_2$ ,  $\text{Y}_2\text{O}_3$ ,  $\text{CeO}_2$ ,  $\text{AlF}_3$ ,  $\text{CaF}_2$ ,  $\text{Na}_3\text{AlF}_6$ ,  $\text{LaF}_3$ ,  $\text{MgF}_2$ ,  $\text{ThF}_4$ ,  $\text{ZnS}$ ,  $\text{Sb}_2\text{O}_3$ ,  $\text{Bi}_2\text{O}_3$ ,  $\text{PbF}_2$ ,  $\text{NdF}_3$ ,  $\text{Nd}_2\text{O}_3$ ,  $\text{Pr}_6\text{O}_{11}$ ,  $\text{SiO}$ ,  $\text{NaF}$ ,  $\text{ZnO}$ ,  $\text{LiF}$  and  $\text{GdO}_3$ .

14. A device according to claim 12 wherein the said at least one further optical film (30, 32, 34, 36) which is partially absorbing is selected from the group comprising,  $\text{Al}$ ,  $\text{Cu}$ ,  $\text{Au}$ ,  $\text{Mo}$ ,  $\text{Ni}$ ,  $\text{Pt}$ ,  $\text{Rh}$ ,  $\text{Ag}$ ,  $\text{W}$ ,  $\text{Cr}$ ,  $\text{Co}$ ,  $\text{Fe}$ ,  $\text{Ge}$ ,  $\text{Hf}$ ,  $\text{Nb}$ ,  $\text{Pd}$ ,  $\text{Re}$ ,  $\text{V}$ ,  $\text{Si}$ ,  $\text{Se}$ ,  $\text{Ta}$ ,  $\text{Y}$ ,  $\text{Zr}$ , Inconel and Nichrome.

## Patentansprüche

1. Optische elektrolumineszente Interferenz-Vorrichtung mit niedriger Reflexion, welche

(a) eine für Elektrolumineszenz durchlässige, opto-elektrische Frontelektrode (2) mit wenigstens einer Schicht, (b) eine opto-elektrische Gegenelektrode (8), die rückseitig zur Frontelektrode angeordnet ist und wenigstens eine Schicht aufweist,

(c) ein opto-elektrisches elektrolumineszentes Teil (10) mit wenigstens einer Schicht, das zwischen der Frontelektrode (2) und der Gegenelektrode (8) angeordnet ist, aufweist und gekennzeichnet ist durch

(d) für wenigstens eines der opto-elektrischen Teile (2, 8, 10) ein optisches Teil (12, 14, 16, 18), das sich im Grenzflächenkontakt damit befindet, so daß wenigstens ein optisches Teil (14, 16) im Grenzflächenkontakt mit der Gegenelektrode (8) steht, wobei das optische Teil (12, 14, 16, 18) wenigstens einen optischen Interferenzfilm (20, 22, 24, 26) aufweist, der im wesentlichen transparent für Umgebungslicht ist, wobei der wenigstens eine optische Interferenzfilm einen Extinktionskoeffizienten aufweist, daß eine Durchlässigkeit per se für einfallendes Licht von wenigstens etwa 90 % bei einer vorbestimmten Wellenlänge besteht, und eine Dicke aufweist und aus einem Material besteht, daß die spektrale Reflexion der elektrolumineszenten Vorrichtung so modifiziert wird, daß die Reflexion von Umgebungslicht durch die elektrolumineszente Vorrichtung in Richtung auf einen Betrachter durch optische Interferenz von partiell an den Grenzflächen des wenigstens einen Filmes (20, 22, 24, 26) reflektierten Lichts in Verbindung mit der des Lichts, das partiell an den Schichten der opto-elektrischen Teile (2, 8, 10) reflektiert wird, reduziert wird.

2. Vorrichtung nach Anspruch 1, worin das optische Teil wenigstens einen weiteren Film (30, 32, 34, 36) aufweist, der im Bezug auf sichtbares Licht partiell absorbierend ausgelegt ist, so daß die Reflexion von Umgebungslicht durch die elektrolumineszente Vorrichtung in Richtung auf den Betrachter weiter durch optische Interferenz-verstärkte Absorption reduziert ist.

3. Vorrichtung nach Anspruch 2, welche weiterhin

(a) ein erstes dielektrisches, für Elektrolumineszenz durchlässiges opto-elektrisches Teil (38), mit wenigstens einer Schicht zwischen der opto-elektrischen Frontelektrode (2) und dem opto-elektrischen elektrolumineszenten Teil (10) und

(b) ein zweites, für Elektrolumineszenz durchlässiges opto-elektrisches Teil (44) mit wenigstens einer Schicht zwischen der opto-elektrischen Gegenelektrode (8) und dem elektrolumineszenten opto-elektrischen Teil (10) aufweist, und worin

(c) das wenigstens eine opto-elektrische Teil (2, 8, 10) von (d), Anspruch 1, das erste und zweite dielektrische opto-elektrische Teil (38, 44) aufweist.

4. Vorrichtung nach Anspruch 2 oder 3, worin die Dicke und die Materialien der Schichten der opto-elektrischen Teile (2, 8, 10) in der Vorrichtung so ausgewählt sind, daß sie die Reflexion der Vorrichtung durch optische Interferenz weiter reduzieren.

5. Vorrichtung nach Anspruch 2, 3 oder 4, worin

(a) die opto-elektrische Gegenelektrode (8) eine hohe Reflexion aufweist und  
 (b) das optische Teil (14) in Grenzflächenkontakt mit der Gegenelektrode (8) im Grenzflächenkontakt mit der Frontseite der Gegenelektrode (8) steht, so daß die Lichtreflexion der Gegenelektrode (8) über das gesamte sichtbare Spektrum, unter Einschluß der Wellenlängen, bei der die Elektrolumineszenz emittiert wird, durch das Verfahren der durch optische Interferenz verstärkten Absorption vermindert wird.

6. Vorrichtung nach Anspruch 2, 3 oder 4, worin

(a) die opto-elektrische Gegenelektrode (8) eine niedrige Reflexion und hohe Durchlässigkeit bei den Wellenlängen aufweist, bei denen die Elektrolumineszenz emittiert wird, und  
 (b) das wenigstens eine optische Teil (16) im Grenzflächenkontakt mit der Rückseite der opto-elektrischen Gegenelektrode (8) steht, und  
 (c) die im wesentlichen transparenten und teilweise absorbierenden Filme (24, 34) des optischen Teils eine solche Dicke und ein solches Material aufweisen, daß, bei den Wellenlängen, bei denen die Elektrolumineszenz emittiert wird, die Reflexion hoch ist, um die Helligkeit der Vorrichtung zu erhöhen, während bei den anderen Wellenlängen die Absorption von Licht hoch ist, um die Reflexion von Umgebungslicht der Vorrichtung in Richtung auf den Betrachter bei diesen anderen Wellenlängen zu vermindern.

7. Vorrichtung nach Anspruch 2, 3 oder 4, worin

(a) die opto-elektrische Gegenelektrode (8) eine hohe Reflexion aufweist und  
 (b) das optische Teil (14) im Grenzflächenkontakt mit der Gegenelektrode (8) im Grenzflächenkontakt mit der Frontseite der Gegenelektrode (8) steht und  
 (c) die im wesentlichen transparenten teilweise absorbierenden Filme (22, 32) des optischen Teils (14) eine solche Dicke und solche Materialien aufweisen, daß, bei den Wellenlängen, bei denen die Elektrolumineszenz emittiert wird, die Durchlässigkeit durch das optische Teil (14) hoch ist, während bei anderen Wellenlängen die Lichtabsorption hoch ist, um die Reflexion von Umgebungslicht der Vorrichtung in Richtung auf den Betrachter bei diesen anderen Wellenlängen zu vermindern.

8. Vorrichtung nach Anspruch 1, 2 oder 3, worin die opto-elektrische Front- und Gegenelektrode (2, 8) jeweils eines einer Vielzahl von opto-elektrischen Elektroden (2, 62, 64; 8, 66, 68, 70) umfassen, wobei die opto-elektrischen Frontelektroden (2, 62, 64) partiell Flächen der opto-elektrischen Gegenelektroden (8, 66, 68, 70) überlagern und eine Anzeige darstellende Vorrichtung bilden.

9. Vorrichtung nach Anspruch 8, worin die opto-elektrischen Front- und Gegenelektroden (2, 62, 64; 8, 66, 68, 70) das Gittersystem eines ein Pixel-Display (72) darstellende Vorrichtung bilden.

10. Vorrichtung nach Anspruch 8 oder 9, worin die Dicke und die Materialien der Filme und Schichten verschiedener Überlagerungen so sind, daß bei jeder Überlagerung, mittels optischer Interferenz, verschiedene Überlagerungsflächen der Vorrichtung die gleiche Reflexion und Durchlässigkeit aufweisen, so daß ein im wesentlichen gleichförmiges Erscheinungsbild der Anzeige erscheint, wenn keine Elektrolumineszenz emittiert wird.

11. Vorrichtung nach Anspruch 1, worin der wenigstens eine optische Film (20, 22, 24, 26), der im wesentlichen transparent ist, eine optische Dicke von wenigstens etwa 0,035  $\mu\text{m}$  aufweist.

12. Vorrichtung nach Anspruch 2, worin der wenigstens eine weitere optische Film (30, 32, 34, 36), der partiell absorbierend ausgelegt ist, eine Durchlässigkeit per se von wenigstens etwa 35 % bei einer vorbestimmten Wellenlänge aufweist.

13. Vorrichtung nach Anspruch 11, worin der wenigstens eine optische Film (20, 22, 24, 26), der im wesentlichen transparent ist, aus der aus  $\text{Al}_2\text{O}_3$ ,  $\text{SiO}_2$ ,  $\text{ZrO}_2$ ,  $\text{HfO}_2$ ,  $\text{Sc}_2\text{O}_3$ ,  $\text{TiO}_2$ , ITO,  $\text{La}_2\text{O}_3$ ,  $\text{MgO}$ ,  $\text{Ta}_2\text{O}_5$ ,  $\text{ThO}_2$ ,  $\text{Y}_2\text{O}_3$ ,  $\text{CeO}_2$ ,  $\text{AlF}_3$ ,  $\text{CeF}_3$ ,  $\text{Na}_3\text{AlF}_6$ ,  $\text{LaF}_3$ ,  $\text{MgF}_2$ ,  $\text{ThF}_4$ ,  $\text{ZnS}$ ,  $\text{Sb}_2\text{O}_3$ ,  $\text{Bi}_2\text{O}_3$ ,  $\text{PbF}_2$ ,  $\text{NdF}_3$ ,  $\text{Nd}_2\text{O}_3$ ,  $\text{Pr}_6\text{O}_{11}$ ,  $\text{SiO}$ ,  $\text{NaF}$ ,  $\text{ZnO}$ ,  $\text{LiF}$  und  $\text{GdO}_3$  bestehenden Gruppe ausgewählt ist.

14. Vorrichtung nach Anspruch 12, worin der wenigstens eine weitere optische Film (30, 32, 34, 36), der partiell absorbierend ausgelegt ist, aus der aus  $\text{Al}$ ,  $\text{Cu}$ ,  $\text{Au}$ ,  $\text{Mo}$ ,  $\text{Ni}$ ,  $\text{Pt}$ ,  $\text{Rh}$ ,  $\text{Ag}$ ,  $\text{W}$ ,  $\text{Cr}$ ,  $\text{Co}$ ,  $\text{Fe}$ ,  $\text{Ge}$ ,  $\text{Hf}$ ,  $\text{Nb}$ ,  $\text{Pd}$ ,  $\text{Re}$ ,  $\text{V}$ ,  $\text{Si}$ ,  $\text{Se}$ ,  $\text{Ta}$ ,  $\text{Y}$ ,  $\text{Zr}$ , Inkonel und Nichrom bestehenden Gruppe ausgewählt ist.

**Revendications**

1. Dispositif électroluminescent à interférence optique présentant une faible réflectance, comprenant :

- 5 (a) un élément d'électrode avant électro-optique transmettant l'électroluminescence (2) comprenant au moins une couche ;
- (b) un élément de contre-électrode électro-optique (8), disposé à l'arrière de l'élément d'électrode avant et comprenant au moins une couche ;
- 10 (c) un élément électroluminescent électro-optique (10) comprenant au moins une couche et disposé entre l'élément d'électrode avant (2) et l'élément de contre-électrode (8); et caractérisé par :
- (d) pour au moins l'un des éléments électro-optiques (2, 8, 10), un élément optique (12, 14, 16, 18) en contact interfacial avec de telle sorte qu'au moins un élément optique (14, 16) soit en contact interfacial avec ledit élément de contre-électrode (8), l'élément optique (12, 14, 16, 18) comprenant au moins un film d'interférence optique (20, 22, 24, 26) qui est sensiblement transparent à la lumière ambiante en ce sens que ledit au moins
- 15 un film d'interférence optique présente un coefficient d'extinction de telle sorte qu'au moins environ 90% de la lumière incidente soit transmise en soi à une longueur d'onde prédéterminée et est d'une épaisseur et en un matériau de telle sorte que la réflectance spectrale dudit dispositif électroluminescent soit modifiée de telle sorte que la réflectance de la lumière ambiante du dispositif électroluminescent en direction d'un observateur soit réduite de l'interférence optique de la lumière partiellement réfléchie au niveau des interfaces dudit au
- 20 moins un film (20, 22, 24, 26) en combinaison avec celle de la lumière partiellement réfléchie au niveau des couches desdits éléments électro-optiques (2, 8, 10).

2. Dispositif selon la revendication 1, dans lequel ledit élément optique comprend au moins un film supplémentaire (30, 32, 34, 36) qui absorbe partiellement la lumière visible de telle sorte que la réflectance de la lumière ambiante du dispositif électroluminescent en direction de l'observateur soit encore réduite de l'absorption améliorée d'inter-

25 fférence optique.

3. Dispositif selon la revendication 2, comprenant en outre :

- 30 (a) un premier élément électro-optique transmettant l'électroluminescence diélectrique (38), comprenant au moins une couche, entre l'élément électro-optique d'électrode avant (2) et l'élément électro-optique électroluminescent (10) ; et
- (b) un second élément électro-optique transmettant l'électroluminescence diélectrique (44), comprenant au moins une couche, entre l'élément électro-optique de contre-électrode (8) et l'élément électro-optique électroluminescent (10), et dans lequel :
- 35 (c) ledit au moins un des éléments électro-optiques (2, 8, 10) de la revendication 1 (d), inclut les premier et second éléments électro-optiques diélectriques (38, 44).

4. Dispositif selon la revendication 2 ou 3, dans lequel les épaisseurs et les matériaux des couches des éléments électro-optiques (2, 8, 10) dans le dispositif sont choisis pour réduire davantage la réflectance du dispositif au moyen d'une interférence optique.

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5. Dispositif selon la revendication 2, 3 ou 4, dans lequel :

- 45 (a) l'élément électro-optique de contre-électrode (8) présente une réflectance élevée ; et
- (b) ledit élément optique (14) en contact interfacial avec ledit élément de contre-électrode (8) est en contact interfacial avec la face avant de l'élément de contre-électrode (8) de telle sorte que la réflectance de la lumière provenant de l'élément de contre-électrode (8) soit réduite sur l'étendue du spectre visible, incluant les longueurs d'onde auxquelles l'électroluminescence est émise, au moyen du processus d'absorption améliorée d'interférence optique.
- 50

6. Dispositif selon la revendication 2, 3 ou 4, dans lequel :

- 55 (a) l'élément électro-optique de contre-électrode (8) présente une réflectance faible et une transmittance élevée aux longueurs d'onde auxquelles l'électroluminescence est émise ; et
- (b) ledit au moins un des éléments optiques (16) est en contact interfacial avec la face arrière de l'élément électro-optique de contre-électrode (8); et
- (c) les films sensiblement transparents et partiellement absorbants (24, 34) de l'élément optique sont d'épais-

seurs et en matériaux qui sont tels que, aux longueurs d'onde auxquelles l'électroluminescence est émise, la réflectance est élevée pour augmenter la luminosité du dispositif tandis qu'à d'autres longueurs d'onde, l'absorbance de la lumière est élevée pour réduire la réflectance de la lumière ambiante du dispositif en direction de l'observateur à ces autres longueurs d'onde.

7. Dispositif selon la revendication 2, 3 ou 4, dans lequel :

- (a) l'élément électro-optique de contre-électrode (8) présente une réflectance élevée ; et
- (b) ledit élément optique (14) en contact interfacial avec ledit élément de contre-électrode (8) est en contact interfacial avec la face avant dudit élément de contre-électrode (8); et
- (c) les films sensiblement transparents et partiellement absorbants (22, 32) de l'élément optique (14) sont d'épaisseurs et en matériaux qui sont tels que, aux longueurs d'onde auxquelles l'électroluminescence est émise, la transmittance au travers de cet élément optique (14) est élevée tandis qu'à d'autres longueurs d'onde, l'absorbance de la lumière est élevée pour réduire la réflectance de la lumière ambiante du dispositif en direction de l'observateur à ces autres longueurs d'onde.

8. Dispositif selon la revendication 1, 2 ou 3, dans lequel les éléments électro-optiques avant et de contre-électrode (2, 8) comprennent chacun l'un d'une pluralité d'éléments électro-optiques d'électrode (2, 62, 64; 8, 66, 68, 70), les éléments électro-optiques d'électrode avant (2, 62, 64) chevauchant partiellement des zones des éléments électro-optiques de contre-électrode (8, 66, 68, 70) pour former un dispositif de représentation d'affichage.

9. Dispositif selon la revendication 8, dans lequel les éléments électro-optiques d'électrode avant et de contre-électrode (2, 62, 64; 8, 66, 68, 70) forment le système de grille d'un dispositif de représentation d'affichage (72) de pixel.

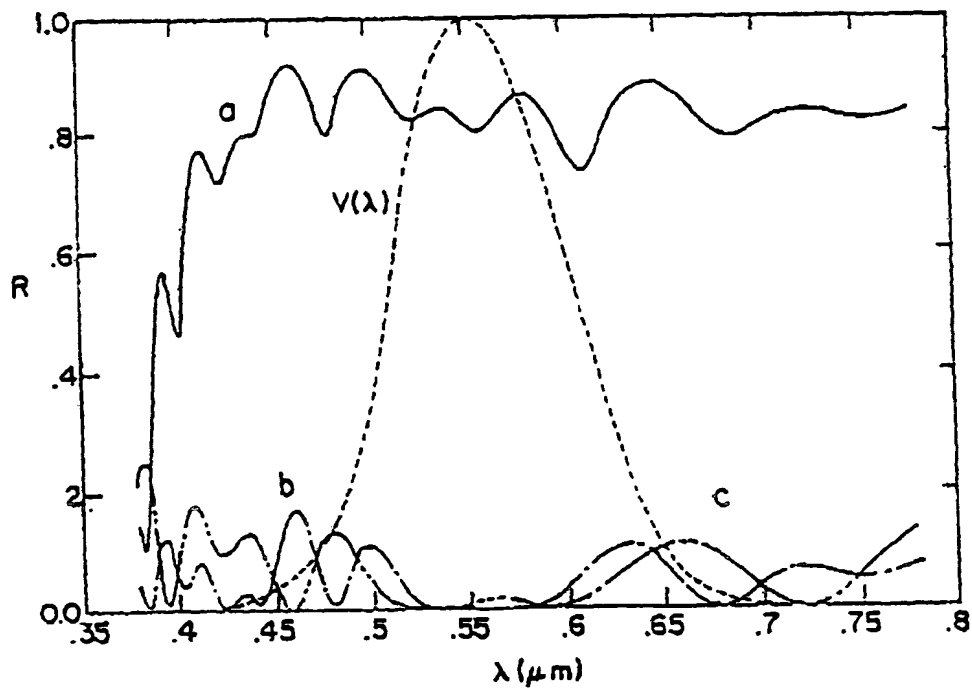
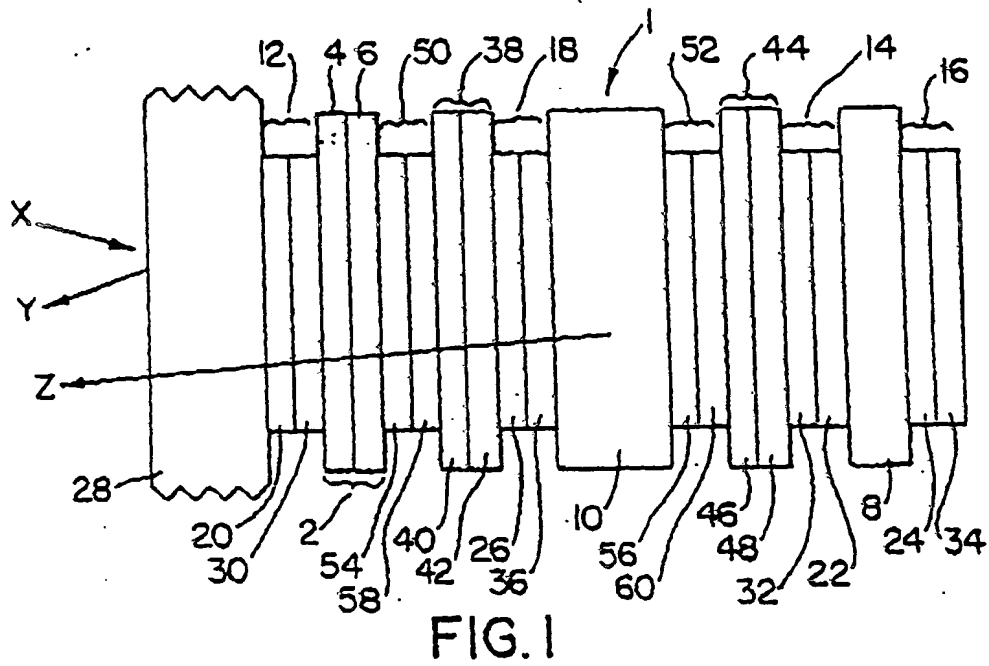
10. Dispositif selon la revendication 8 ou 9, dans lequel les épaisseurs et les matériaux des films et couches de différentes sur-couches sont tels que pour chaque sur-couche, au moyen du processus d'interférence optique, différentes zones de sur-couche du dispositif présentent la même réflectance et la même transmittance de telle sorte qu'une apparence sensiblement uniforme de l'affichage soit observée lorsqu'aucune électroluminescence n'est en train d'être émise.

11. Dispositif selon la revendication 1, dans lequel ledit au moins un film optique (20, 22, 24, 26) qui est sensiblement transparent présente une épaisseur optique d'au moins environ 0,035  $\mu\text{m}$ .

12. Dispositif selon la revendication 2, dans lequel ledit au moins un film optique supplémentaire (30, 32, 34, 36) qui est partiellement absorbant présente une transmittance en soi d'au moins environ 35% à une longueur d'onde prédéterminée.

13. Dispositif selon la revendication 11, dans lequel ledit au moins un film optique (20, 22, 24, 26) qui est sensiblement transparent est choisi parmi le groupe comprenant :  $\text{Al}_2\text{O}_3$ ,  $\text{SiO}_2$ ,  $\text{ZrO}_2$ ,  $\text{HfO}_2$ ,  $\text{Sc}_2\text{O}_3$ ,  $\text{TiO}_2$ , ITO,  $\text{La}_2\text{O}_3$ ,  $\text{MgO}$ ,  $\text{Ta}_2\text{O}_5$ ,  $\text{ThO}_2$ ,  $\text{Y}_2\text{O}_3$ ,  $\text{CeO}_2$ ,  $\text{AlF}_3$ ,  $\text{CeF}_3$ ,  $\text{Na}_3\text{AlF}_6$ ,  $\text{LaF}_3$ ,  $\text{MgF}_2$ ,  $\text{ThF}_4$ ,  $\text{ZnS}$ ,  $\text{Sb}_2\text{O}_3$ ,  $\text{Bi}_2\text{O}_3$ ,  $\text{PbF}_2$ ,  $\text{NdF}_3$ ,  $\text{Nd}_2\text{O}_3$ ,  $\text{Pr}_6\text{O}_{11}$ ,  $\text{SiO}$ ,  $\text{NaF}$ ,  $\text{ZnO}$ ,  $\text{LiF}$  et  $\text{GdO}_3$ .

14. Dispositif selon la revendication 12, dans lequel ledit au moins un film optique supplémentaire (30, 32, 34, 36) qui est partiellement absorbant est choisi parmi le groupe comprenant :  $\text{Al}$ ,  $\text{Cu}$ ,  $\text{Au}$ ,  $\text{Mo}$ ,  $\text{Ni}$ ,  $\text{Pt}$ ,  $\text{Rh}$ ,  $\text{Ag}$ ,  $\text{W}$ ,  $\text{Cr}$ ,  $\text{Co}$ ,  $\text{Fe}$ ,  $\text{Ge}$ ,  $\text{Hf}$ ,  $\text{Nb}$ ,  $\text{Pd}$ ,  $\text{Re}$ ,  $\text{V}$ ,  $\text{Si}$ ,  $\text{Se}$ ,  $\text{Ta}$ ,  $\text{Y}$ ,  $\text{Zr}$ , Inconel et Nichrome.



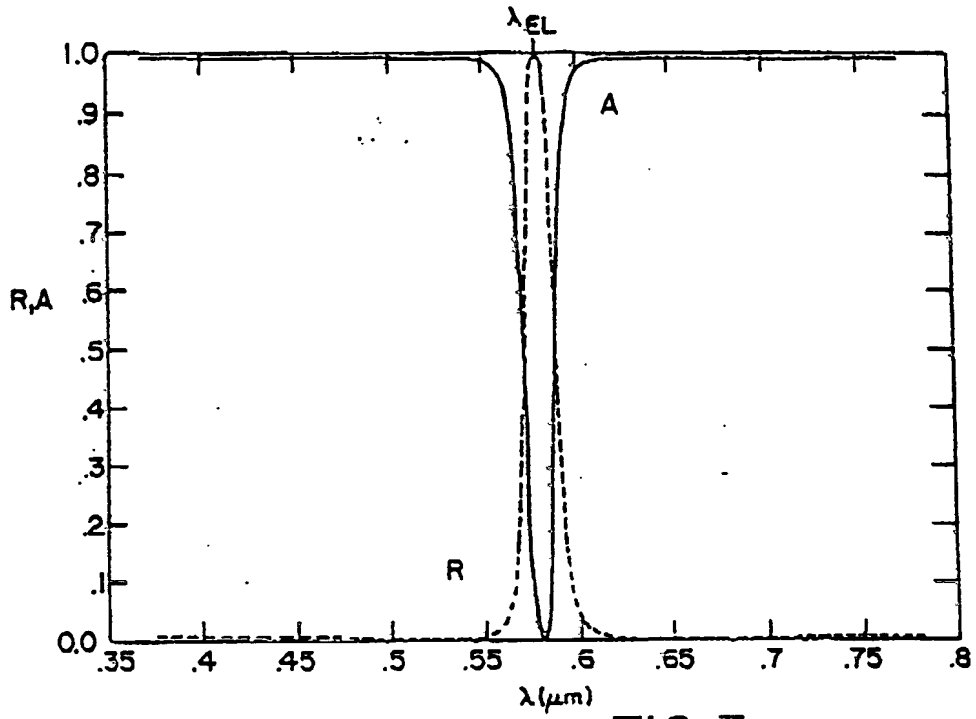


FIG. 3

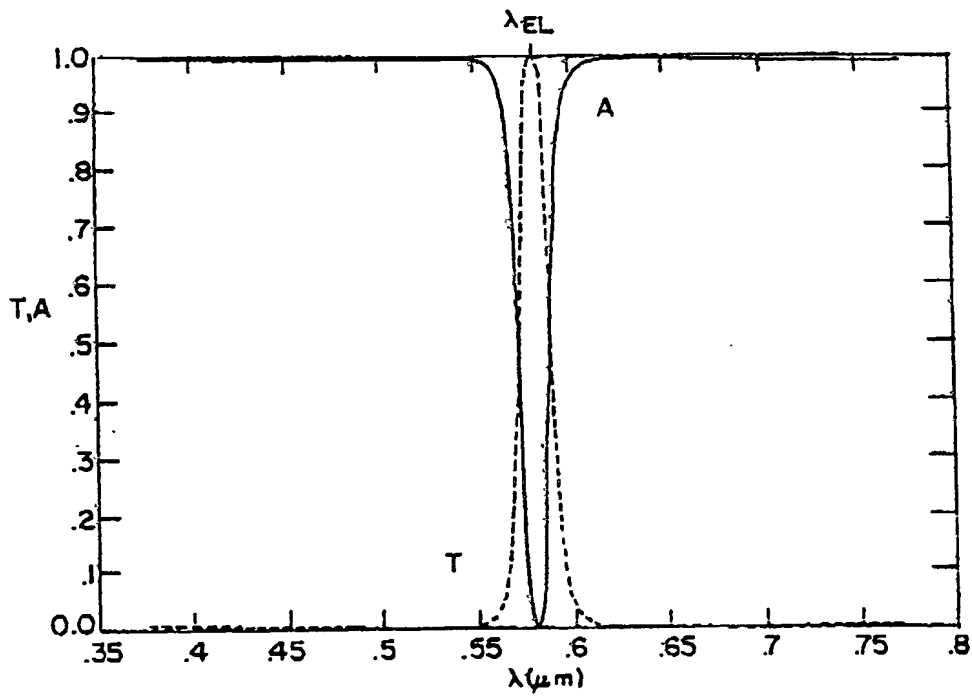


FIG. 4



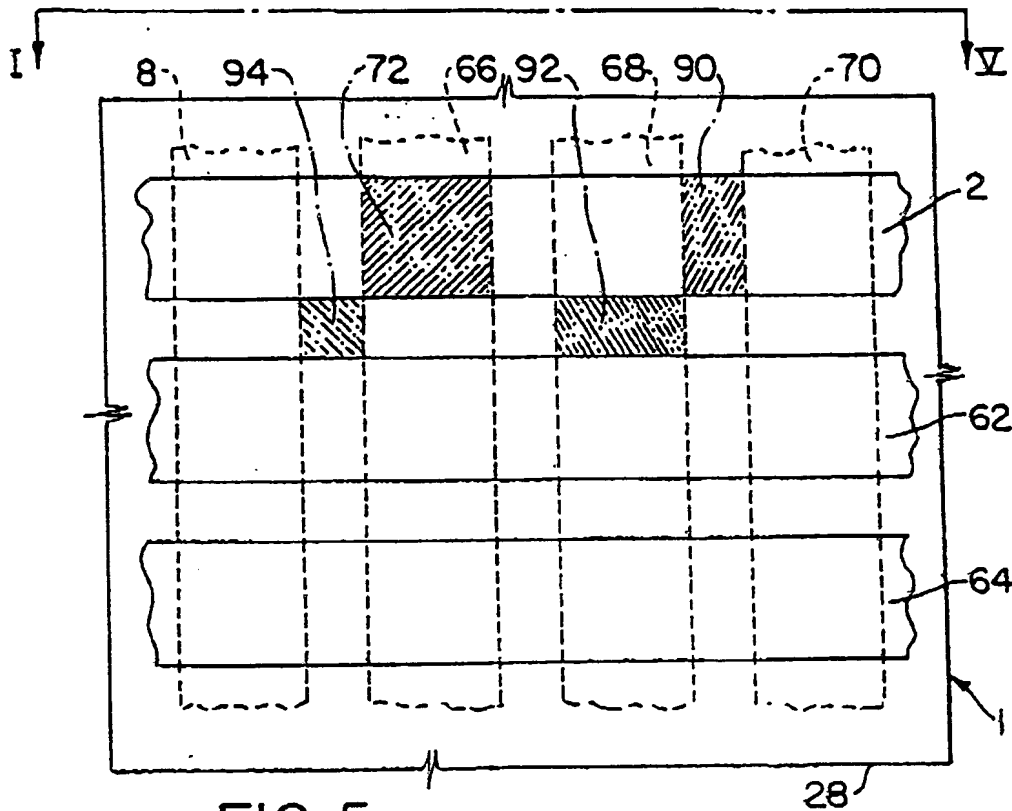


FIG. 5

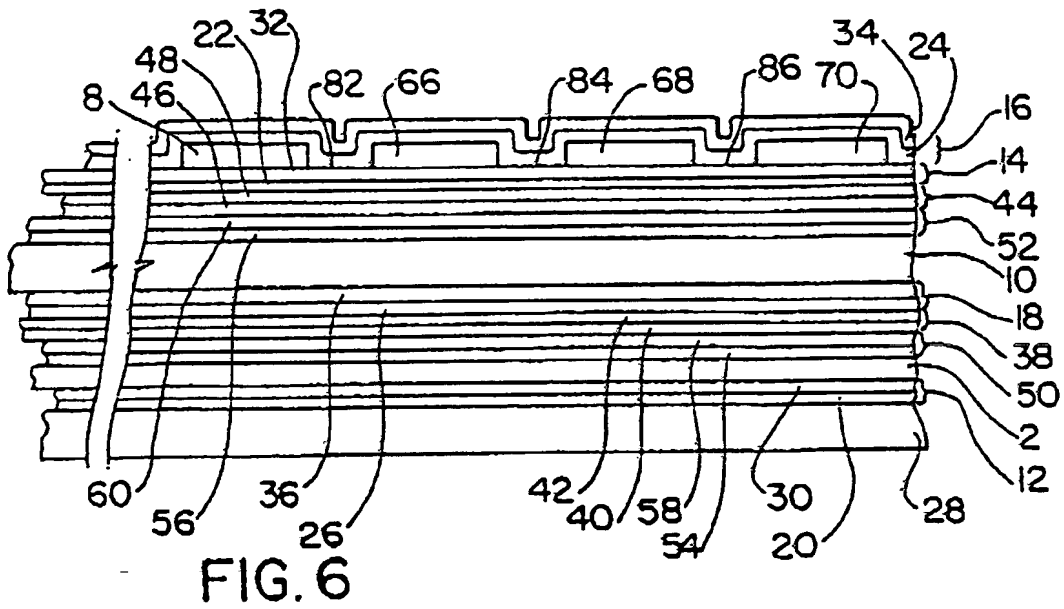


FIG. 6



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(54) An optical interference, electroluminescent device having low reflectance.

(57) An optical interference electroluminescent device having low reflectance comprises three layers forming an electroluminescent transparent front electrode, a counter electrode and an electroluminescent layer between the electrodes, with or without dielectric layers between them, and at least one optical interference film layer sandwiched between two of the layers or at the faces of the electrodes. The optical interference layer comprises at least one transparent optical interference film and is in interfacial contact with a layer so that the reflectance of ambient light by the device is reduced by optical interference at the interfaces between the layers and the film(s). The optical interference layer(s) may include at least one partially absorbing film. The device may have arrays of electrodes forming pixels.

EP 0 372 763 A3

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# EUROPEAN SEARCH REPORT

Application Number

EP 89 31 2213

| DOCUMENTS CONSIDERED TO BE RELEVANT                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                                                                                        |                                             |                                               |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------|---------------------------------------------|-----------------------------------------------|
| Category                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | Citation of document with indication, where appropriate, of relevant passages                                          | Relevant to claim                           | CLASSIFICATION OF THE APPLICATION (Int. Cl.5) |
| X                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | DD-A-2 535 38 (VEB)<br>* the whole document *<br>- - - -                                                               | 1-6                                         | H 05 B<br>33/22                               |
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| E                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Patent Office of Japan,file suppliers JAPS<br>& JPA 2056892 (NIPPON SHEET GLASS) 26-02-90<br>* abstract *<br>- - - - - | 1,3                                         |                                               |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                                                                                        |                                             | TECHNICAL FIELDS<br>SEARCHED (Int. Cl.5)      |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                                                                                        |                                             | H 05 B                                        |
| The present search report has been drawn up for all claims                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                                                                                        |                                             |                                               |
| Place of search<br>The Hague                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                                                        | Date of completion of search<br>18 March 91 | Examiner<br>DROUOT M.C.                       |
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